ON COMETS AND METEORS.

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The comets which passed their perihelia in August, 1862, and January, 1866, will ever be memorable in the annals of science, as having led to the discovery of the intimate relationship between comets and meteors. These various bodies found revolving about the sun in very eccentric orbits may all be regarded as similar in their nature and origin, differing mainly in the accidents of magnitude and density. The recent researches, moreover, of Hoek, Leverrier and Schiaparelli, have led to the conclusion that such objects exist in great numbers in the interstellar spaces ; that in consequence of the sun's progressive motion they are sometimes drawn towards the centre of our system ; and that if undisturbed by any of the large planets they again pass off in parabolas or hyperbolas. When, however, as must sometimes be the case, they approach near Jupiter, Saturn, Uranus or Neptune, their orbits may be transformed into ellipses. Such, doubtless, has been the origin of the periodicity of the August and November meteors, as well as of numerous comets.

In the present paper it is proposed to consider the probable consequences of the sun's motion through regions of space in which cosmical matter is widely diffused ; to compare these theoretical deductions with the observed phenomena of comets, ærolites and falling stars ; and thus, if possible, explain a variety of facts in regard to those bodies, which have hitherto received no satisfactory explanation.

1. As comets now moving in elliptic orbits owe their periodicity to the disturbing action of the major planets, and as this planetary influence is sometimes sufficient, especially in the case of Jupiter and Saturn, to change the *direction* of cometary motion, the great majority of periodic comets should move in the same direction with the planets. Now, of the comets known to be elliptical, 70 per cent. *have direct motion.* In this respect, therefore, theory and observation are in striking harmony.

2. When the relative positions of a comet and the disturbing planet are such as to give the transformed orbit of the former a small perihelion distance, the comet must return to the point at which it received its greatest perturbation ; in other words, to the orbit of the planet. The aphelia of the comets of short period ought therefore to be found, for the most part, *in the vicinity of the orbits of the major planets.* The actual distances of these aphelia are as follows :

I. *Comets whose Aphelion Distances are Nearly Equal to* 5.20, *the Radius of Jupiter's Orbit.*

Comets.	*Aph. Dist.*	*Comets.*	*Aph. Dist.*
1. Encke's	4.09	7. 1766 II.	5.47
2. 1819 IV.	4.81	8. 1819 III.	5.55
3. De Vico's	5.02	9. Brorsen's	5.64
4. Pigott's (1743)	5.28	10. D'Arrest's	5.75
5. 1867 I1.	5.29	11. Faye's	5.93
6. 1743 I.	5.32	12. Biela's	6.19

II. *Comets whose Aphelion Distances are Nearly Equal to* 9.54, *the Radius of Saturn's Orbit.*

Comets.	*Aph. Dist.*
1. Peters' (1846 VI.)	9.45
2. Tuttle's (1858 I.)	10.42

III. *Comets whose Aphelion Distances are Nearly Equal to* 19.18, *the Radius of Uranus's Orbit.*

Comets.	*Aph. Dist.*
1. 1867 I.	19.28
2. Nov. Meteors.	19.65
3. 1866 I.	19.92

IV. *Comets whose Aphelion Distances are Nearly Equal to* 30.04, *the Radius of Neptune's Orbit.*

Comets.	*Aph. Dist*	*Comets.*	*Aph. Dist.*
1. Westphal's (1852 IV.)	31.97	4. De Vico's (1846 IV.)	34.35
2. Pons' (1812)	33.41	5. Brorsen's (1847 V.)	35.07
3. Olbers' (1815)	34.05	6. Halley's	35.37

The coincidences here pointed out (some of which have been noticed by others,) appear, then, to be necessary consequences of the motion of the solar system through spaces occupied by meteoric nebulæ. Hence the observed facts receive an obvious explanation.

In regard to comets of long period we have only to remark that, for any thing we know to the contrary, there may be causes of perturbation far exterior to the orbit of Neptune.

3. From what we observe in regard to the *larger* bodies of the universe —a clustering tendency being everywhere apparent,—it seems highly improbable that *cometic and meteoric* matter should be uniformly diffused through space. We would expect, on the contrary, to find it collected in cosmical clouds, similar to the visible nebulæ. Now, this, in fact, is precisely what has been observed in regard both to comets and meteors. In

150 years, from 1600 to 1750, 16 comets were visible to the naked eye;* of which 8 appeared in the 25 years from 1664 to 1689. Again, during 60 years, from 1750 to 1810, only 5 comets were visible to the naked eye, while in the next 50 years there were double that number. The probable cause of such variations is sufficiently obvious. As the sun in his pro-progressive motion approaches a cometary group, the latter must, by reason of his attraction, move toward the centre of our system, the nearer members with greater velocity than the more remote. Those of the same cluster would enter the solar domain at periods not very distant from each other; the forms of their orbits depending upon their original relative positions with reference to the sun's course, and also on planetary perturbation. It is evident also that the passage of the solar system through a region of space comparatively destitute of cometic clusters would be indicated by a corresponding paucity of comets. By the examination, moreover, of any complete table of falling stars we shall find a still more marked variation in the frequency of meteoric showers.

Previous to 1833, the periodicity of shooting stars had not been suspected. Hence the showers seen up to that date were observed *accidentally*. Since the great display of that year, however, they have been regularly *looked for*, especially at the November and August epochs. Consequently the numbers recently observed cannot properly be compared with those of former periods. Now, according to the Catalogue of Quetelet, 244 meteoric showers were observed from the Christian era to 1833. These were distributed as follows:

Centuries.	*No. of Showers.*	*Centuries.*	*No. of Showers.*
0 to 100	5	1000 to 1100	22
100 to 200	0	1100 to 1200	12
200 to 300	3	1200 to 1300	3
300 to 400	1	1300 to 1400	4
400 to 500	1	1400 to 1500	4
500 to 600	20	1500 to 1600	7
600 to 700	1	1600 to 1700	7
700 to 800	14	1700 to 1800	24
800 to 900	37	1800 to 1833	48
900 to 1000	31		

A remarkable secular variation in the number of showers is obvious from the foregoing table. During the 5 centuries from 700 to 1200, 116 displays are recorded; while in the 5 succeeding, from 1200 to 1700, the number is only 25. It will also be observed that another period of abundance commenced with the 18th century. A catalogue of meteoric stonefalls indicates also a corresponding increase in the number of ærolites, which cannot be wholly accounted for by the increased number of observers. Now, there are two obvious methods by which these variations may be explained. Either (1) the orbits of the meteoric rings which

*See Humboldt's Cosmos, vol. IV. p. 538, The writer called attention to this variation as long since as 1861.

intersect the earth's path were so changed by perturbation towards the close of the 12th century as to prevent the appulse of the meteoric groups with the earth's atmosphere ; or, (2) the nebulous matter is very unequally diffused through the sidereal spaces. That the former has not been the principal cause is rendered extremely probable by the fact that the number of epochs of periodical showers was no greater during the cycle of abundance than in that of paucity. We conclude, therefore, that during the interval from 700 to 1200 the solar system was passing through, or near, a meteoric cloud of very great extent ; that from 1200 to 1700 it was traversing a region comparatively destitute of such matter ; and that about the commencement of the 18th century it again entered a similar nebula of unknown extent.

The fact that the August meteors, which have been so often subsequently observed, were *first* noticed in 811, renders it probable that the cluster was introduced into the planetary system not long previous to the year 800. It may be also worthy of remark that the elements of the comet of 770 A. D., are not very different from those of the August meteors and the 3d comet of 1862.*

Adopting Struve's estimate of the sun's orbital velocity, we find the diameter of the nebula traversed in 500 years to be 14 times that of Neptune's orbit.

It is remarkable that with the exception of Mars the perihelia of the orbits of all the principal planets fall in the same semi-circle of longitude—a fact which can hardly be regarded as accidental. Now, if the orbits were orginally circular, the motion of the solar system through a nebulous mass not of uniform density would have the obvious effect of compelling the planets to deviate from their primitive orbits and move in ellipses of various eccentricities. It is easy to perceive, moreover, that the original perihelion points of all the orbits would be on that side of the system which had passed through the rarer portion of the nebulous mass. We have thus a possible cause of the eccentricity of the planetary orbits, as well as of the observed distribution of their perihelia.†

4. The particles of a cometic mass, being at unequal distances from the sun, will tend to move at different rates and in somewhat different orbits. This tendency will gradually overcome the feeble attractive force between the particles themselves. The most distant parts will thus become separated from the nucleus, and move in independent orbits. The motion of such meteoric matter will be in the same plane with that of the parent comet ; the orbit of the former, however, being generally exterior to that of the latter. The connection recently discovered between comets and meteors, and especially the fact that the period of the

* The interval between the perihelion passage of 770 and that of 1862 is equal to 9 periods of 121.36 years. Oppolzer's determination of the period of 1862 III. is 121.5 years. Hind remarks that the elements of the comet of 770 are "rather uncertain," but says "that the general character of the orbit is decided." It may be worthy of remark that a great meteoric shower, the exact date of which has not been preserved, occurred in 770.

† This suggestion is due to R. A. Proctor, F. R. A. S., the distinguished author of "Saturn and its System."

November group is somewhat greater than that of the comet of 1866, are in striking harmony with the views here presented.

5. Owing to this loss of matter, periodic comets must become less brilliant, other things being equal, at each successive return ;—a fact observed in regard to the comets of Halley and Biela.

6. The line of apsides of a large proportion of comets will be approximately coincident with the solar orbit. The point towards which the sun is moving is in longitude about 260°. The quadrants bisected by this point and that directly opposite extend from 215° to 305°, and from 35° to 125°. The number of cometary perihelia found in these quadrants up to July, 1868, (periodic comets being counted but once) was 159, or 62 per cent.; in the other two quadrants, 98, or 38 per cent.

This tendency of the perihelia to crowd together in two opposite regions has been noticed by different writers.

7. Comets whose positions before entering our system were very remote from the solar orbit must have *overtaken* the sun in its progressive motion; hence their perihelia must fall for the most part, in the vicinity of the point towards which the sun is moving; and they must in general have very small perihelion distances. Now, what are the observed facts in regard to the longitudes of the perihelia of the comets which have approached within the least distance of the sun's surface? But three have had a perihelion distance less than 0.01. *All* these, it will be seen by the following table, have their perihelia in close proximity to the point referred to:

I. *Comets whose Perihelion Distances are Less than* 0.01.

	Perihelion Passage.			*Per. Dist.*	*Long. of Per.*	
1.	1668, Feb.	28*d.*	13*h.*	0.0047	277°	2′
2.	1680, Dec.	17	23	0.0062	262	49
3.	1843, Feb.	27	9	0.0055	278	39

In table II. all but the last have their perihelia in the same quadrant.

II. *Comets whose Perihelion Distances are Greater than* 0.01 *and Less than* 0.05.

	Perihelion Passage.			*Per. Dist.*	*Long. of Per.*	
1.	1689, Nov.	29*d.*	4*h.*	0.0189	269°	41′
2.	1816, March	1	8	0.0485	267	35
3.	1826, Nov.	18	9	0.0268	315	31
4.	1847, March	30	6	0.0425	276	2
5.	1865, Jan.	14	7	0.0260	141	15

The perihelion of the first comet in table III. is remote from the direction of the sun's motion; that of the second is distant but 14°, and of the third, 21°.

III. *Comets whose Perihelion Distances are Greater than* 0.05 *and Less than* 0.1.

Perihelion Passage.	Per. Dist.	Long. of Per.
1. 1593, July 18*d.* 13*h.*	0.0891	176° 19′
2. 1780, Sept. 30 22	0.0963	246 35
3. 1821, March 21 12	0.0918	239 29

With greater perihelion distances the tendency of the perihelia to crowd together around the point indicated is less distinctly marked.

8. Few comets of small perihelion distance should have their perihelia in the vicinity of longitude 80°, the point opposite that towards which the sun is moving. Accordingly we find, by examining a table of cometary elements, that with a perihelion distance less than 0.1, there is not a single perihelion between 35° and 125°; between 0.1 and 0.2, but 3; and between 0.2 and 0.3 only 1.

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A SEARCH FOR A NORMAL CAUSE OF THE RECESSION OF COSMICAL NODES.

By Hon. Walter H. Lowrie.

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The analogy between the recession of the nodes of all the planets and satellites of the solar system, including that of the earth, called the precession of the equinoxes, is so complete and manifest that the mind, on the discovery of it, naturally inclines to attribute them all to like causes. These phenomena have not been so treated heretofore, but have been regarded as disturbances produced by various causes, the influence of which I do not feel entitled to question, while I think there is a normal cause which ought to be considered.

It seems to me to be a proposition of axiomatic plainness, that, in any system or sub-system of moving bodies, all its periodic motions ought to be presumed normal, rather than abnormal, that is, the causes of them ought to be first sought in the plan of the system itself; and only when this search fails ought we to suspect them to be disturbances caused by forces which are alien to the system. Thus, all the periodic motions of the planets ought to be presumed to depend on their relation to the sun, until the contrary appears; and all the periodic motions of the satellites ought to be presumed to depend upon their several planets.